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**Madsen, Jens; Hahm, T.S.**

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# Gyrokinetic equations for tokamak turbulence, including a time dependent, background electric field

J. Madsen<sup>1\*</sup>, T.S. Hahm<sup>2</sup>

<sup>1</sup> Association EURATOM-Risø DTU, Technical University of Denmark, DK-4000 Roskilde, Denmark

<sup>2</sup> Princeton Plasma Physics Laboratory, Princeton University, P.O. Box 451, Princeton,  
New Jersey 08543, USA

\* Email: jmad@risoe.dtu.dk

We present an extension of existing gyrokinetic Vlasov-Maxwell equations[1] for edge turbulence to include a time-dependent, strong, sheared ExB-flow. The inclusion of a non-stationary strong ExB flow is required if one tries to apply the gyrokinetic formalism to the H-mode transition and ELM bursts. The H-mode transition[2] and ELM bursts[3] are associated with the formation and changes of a strong, radial electric field  $E_r$  which varies on a time scale on the order of  $\sim 100 \mu s$ . Terms, previously neglected, in the gyrokinetic equations associated with the explicit time-dependence of  $E_r$ , must therefore be retained.

A nonlinear, fully electromagnetic set of gyrokinetic Vlasov-Maxwell equations, including a time dependent background electric field, has been derived. In comparison with previous results, the appearance of the polarization drift, and a time dependent volume element, are the main implications of having an explicit time dependent, background electric field. A local energy theorem is also presented. The results are derived in both “flavours” of the gyrokinetic formalism; symplectic and Hamiltonian.

[1] T.S. Hahm, L. Wang, J. Madsen, Phys. Plasmas, 16, 022305, (2009).

[2] L Zeng et al, PPCF, 46(5A):A121–A129, (2004); Moyer et al, Phys. Plasmas, 2(6),2397, 1995.

[3] A. Kirk et al, Phys. Rev. Lett., 92(24), (2004); I. Nunes et al, Nuclear Fusion,45(12),1550, (2005).